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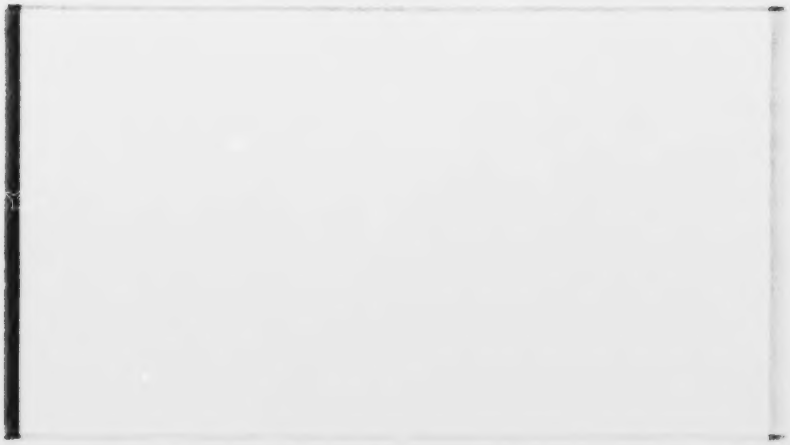

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TECHNIQUES TO ASSESS THE MECHANICAL CHARACTERISTICS OF PLUTONIC ROCK

Report No: 86-7-K

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ABSTRACT

A variety of rock mass characterization techniques were tested under laboratory and/or field conditions as part of the Technical Assistance Program to Atomic Energy of Canada Limited to assess the mechanical characteristics of plutonic rock. The techniques and equipment addressed include the shallow borehole dilatometer, the deep borehole dilatometer, acoustic stress measurement, the impression packer and the sliding micrometer. In general, these techniques appear promising but require further testing and evaluation in plutonic rock.

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TECHNIQUES TO ASSESS THE MECHANICAL CHARACTERISTICS OF PLUTONIC ROCK

1.0 INTRODUCTION

As part of Ontario Hydro's Technical Assistance Program (TAP) to Atomic Energy of Canada Limited, a variety of rock mass characterization techniques were tested under laboratory and/or field conditions. This program was initiated in response to AECL's geomechanics program as discussed by Simmons et al (1985). One of the main objectives of the program was "to develop and test the methodologies, techniques and equipment necessary to assess the mechanical characteristics of plutonic rock of the Canadian Shield".

It was originally intended that some of the techniques (ie borehole dilatometer) would be carried out at the Underground Research Laboratory (URL) near Pinawa, Manitoba. These plans were postponed as a result of AECL's decision to increase the depth of the access shaft at the URL. Regardless of this fact, several techniques were tested and evaluated under laboratory conditions in some cases and under field conditions at alternate field sites in others. The techniques and equipment that were addressed include:

1) the shallow borehole dilatometer,
2) the deep borehole dilatometer,
3) acoustic stress measurements,
4) the impression packer and
5) the sliding micrometer.

2.0 ASSESSMENT TECHNIQUES

2.1 Shallow Borehole Dilatometer

The computerized borehole dilatometer system was used to determine the in situ deformation modulus of sandstone surrounding two circular tunnels in the Donkin Mines near Sydney, Nova Scotia. Although the majority of our studies are concentrated in crystalline rock, the opportunity to test two completely different excavation techniques in the same rock type arose. Regardless of the fact that these two tunnels were

excavated in low modulus sandstone, it was decided that valuable information relating to excavation disturbance could be obtained from this study.

One tunnel was excavated using a tunnel boring machine (TBM), while the second tunnel was mined using drill and blast techniques. An EX borehole was drilled from one tunnel to the other, a distance of approximately 42 metres. Deformation modulus testing was conducted in this drillhole from both tunnels. This work was performed as a subcontract to Golder Associates with Ontario Hydro Research making a financial contribution as well.

Based on the results obtained from this program, it appears that the drill and blast procedures caused greater excavation disturbance than the TBM technique as a result of both blast damage and stress relaxation. The results obtained from both tunnels suggest the influence of the in situ stress field. This means that high stresses are indicative of high moduli and vice versa. Typically, an excavation which has been carefully mined will show high tangential stresses surrounding the opening. The stress values will then drop off with depth and level out at a distance of approximately one tunnel diameter. The tunnel, which was excavated using a tunnel boring machine showed this type of behaviour based on the deformation moduli results obtained. On the contrary, if an excavation is mined using poorly controlled procedures, the tangential stresses will be low surrounding the opening due to distressing as a result of rock damage. This disturbed zone will extend with depth to the point of no further damage. At this boundary, the tangential stresses increase where the rock is more elastic and then drop with depth before levelling out. The tunnel, which was mined using drill and blast procedures, showed indications of this type of behaviour. In summary, the computerized dilatometer system has satisfactorily provided in situ deformation moduli in low modulus sandstone surrounding two circular tunnels. The results indicate that the moduli were influenced by the in situ tangential stress field. Mining procedures using a tunnel boring machine has been shown to cause less excavation disturbance than drill and blast techniques. With depth, more constant deformation moduli were obtained.

An Ontario Hydro Research Division Report (No 85-72-H) entitled "The Determination of In Situ Deformation Modulus - Donkin Mines - Nova Scotia" by R. Koopmans and R.W. Hughes was released on March 1, 1985. This report describes the techniques and results of this program in greater detail.

2.2 Deep Borehole Dilatometer

Site selection for potential nuclear waste repositories will involve drilling deep boreholes in bedrock and obtaining as much

information as possible with a minimum amount of disturbance. Tools and techniques are required to test the rock mass at depth in relatively small boreholes. They should also replace the need for drilling or excavating expensive shafts for obtaining preliminary site information. Some parameters which are of importance are the stress field, the deformation properties and the existence of fractures.

A deep borehole dilatometer is being developed to provide information on all of the parameters indicated above. The tool comprises a pressure intensifier used in conjunction with a dilatometer head, the two being rigidly interconnected so as to be lowered into a borehole. The pressure intensifier consists of a cylindrical housing containing upper and lower cylinders, and a double action piston which provides a 6 to 1 differential between the input pressure side and the output pressure side. Pressure changes are measured by means of a pressure transducer, and volumetric changes are determined from measurements of the linear displacement of the piston. Such linear displacements are measured by means of a shaft encoder coupled to a motion translating device for translating linear displacement into rotary displacement.

The dilatometer will be capable of determining the deformation properties of the rock in a similar fashion to that used in the shallow borehole dilatometer. The deformation modulus results obtained in this manner will provide information with respect to which zones are fractured, sheared, or jointed, etc. Low values indicate disturbed zones, while high values basically indicate undisturbed or minimally disturbed zones. Fractures are not only detected by the low modulus results obtained, but also by impressions which the tool is capable of taking. This is discussed in more detail in section 2.4 (Impression Packer).

Acoustic emission transducers will be incorporated into the borehole dilatometer in an attempt to determine in situ stresses. This item will be discussed further in the next section (Acoustic Stress Measurements).

2.3 Acoustic Stress Measurements

A knowledge of the stress magnitudes and directions in the rock mass is very important with respect to the design aspects of the proposed vault. Stress parameters will dictate both the tunnel shape and the orientations of the tunnel axis. Useful stress information has been obtained by using shallow techniques such as the USBM gauge and the CSIRO gauge. The major concern is the determination of stresses at depth. At this time, hydraulic fracturing is the only technique used in deep stress measurements. Principal stress direction errors as great as 45 degrees have occurred while using this technique. As such, further development is urgently required in the field of stress

measurements at depth.

In hydraulic fracturing, the error in stress direction may be caused by having fractures initiated at weak points in the rock mass by the stresses administered by the pressurized water. By using a dilatometer membrane to cause the fracturing, this problem could be eliminated and possibly provide more accurate stress directions.

It is anticipated that acoustic emission testing will be incorporated into the deep borehole dilatometer as an attempt to determine the in situ stress field in a borehole. This will be attempted by using the hydraulic fracturing technique in which the rock is pressurized and fractured in order to obtain the principal stress direction and secondary stress magnitude. Subsequent to testing, the principal stress magnitudes are calculated from the field data provided. Acoustic transducers will be used in an effort to determine the onset of the membrane induced fracture and hopefully, the reopening of the fracture subsequent to depressurization and repressurization.

The Rock Sciences Section, Civil Research Department has in their possession a PAC 3104 acoustic emission analyzer with signal processors and filters on each of four channels to measure counts, events, peak amplitude, energy, rise time, duration, elapsed time, time difference, time of arrival, rate, parametrics and location. This unit, in conjunction with miniature acoustic sensors (Dunegan model S9225-M1), will be used to record the rock behaviour during the testing program.

2.4 Impression Packer

The determination of excavation damage in the rock mass surrounding the shafts and works of underground storage facilities is important in locating potential pathways for radioactive waste migration. Techniques are being assessed to determine the extent of excavation damage and the excavation procedure which causes the least damage.

The borehole dilatometer has been used as an impression packer by wrapping electrical tape around it and expanding the membrane in a borehole. The electrical tape is forced against the borehole wall and leaves an impression of the rock surface. To date, many features such as fractures, joints and bedding planes have been so recorded. Fractures which were not visible with the naked eye have been observed with the aid of an optical microscope. Features on the tape impression can also be photographed for a permanent record.

It is strongly believed that with a few more modifications, this technique could be very useful in the assessment of blast damage and excavation methods. Suggested modifications should include

a) increasing the length of the membrane to one-half metre to speed up testing and b) increase the width of the tape to minimize the number of ridges which could obscure the features.

2.5 Sliding Micrometer

The Sliding Micrometer-ISETH is a borehole probe, which is used to measure the variation of axial strain along boreholes with a high degree of precision. In this way, the opening or closure of significant discontinuities, which an instrumented borehole intersects, can be observed.

This equipment has been purchased by the Rock Sciences Section (Civil Research) and was demonstrated at the Ontario Power Generating Station which is located beside Niagara Falls. It has been installed to monitor rock mass movement towards the river. Personnel from AECL were invited to observe the installation and reading of the equipment. This demonstration has helped the Rock Mechanics staff at AECL in realizing the usefulness of this tool in their own studies at the URL. They have since this time purchased their own equipment.

A brief description of the measuring technique of the Sliding Micrometer, as described by Kovari and Peter (1983), is provided below. In order to obtain the complete distribution of strain along a straight line, a hard PVC tube containing ring-shaped measuring marks at regular intervals of one metre is grouted into the borehole. These measuring marks, made of steel, serve on the one hand as coupling elements between two adjacent units of PVC tubes and on the other hand as a housing for stop fittings. The latter have the function of holding the two heads of the portable device in position during the short time of a reading. The tube segments are screwed into the ring marks and the stop fittings are fixed in by bolting. All connections are such that the whole assembly is sufficiently robust for lowering into a deep borehole of any direction. If the measuring marks displace relative to each other due to the deformation of the surrounding rock, then the change in distance, ie the strain with the base length of one metre, can be recorded as the difference between two readings.

Further details on the rock and the technique, which was performed at the Ontario Power Generating Station, will be provided in a report being prepared by Mr. D.A. McKay of the Rock Sciences Section, Civil Research Department.

3.0 SUMMARY AND RECOMMENDATIONS

1) The shallow borehole dilatometer has shown promising results with respect to determining the extent of excavation disturbance and assessing the effectiveness of different blasting techniques. Further detailed testing is required, especially in high modulus

granite. It is anticipated that this work will be carried out at the URL in the fall of 1986.

2) The deep borehole dilatometer has the potential of being an extremely useful tool in the assessment of rock masses for potential storage sites. The ability to obtain information on rock properties (ie deformation modulus, stress magnitude and direction, and fracture impressions) in relatively small diameter boreholes, as opposed to excavating expensive shafts, is very promising. Further testing and development is required to increase the versatility of this instrument.

3) The use of acoustic emission equipment to measure in situ stresses could be very useful especially if more accuracy on the principal stress direction could be obtained as compared to that presently available from hydraulic fracturing. Further work is required to determine the full capabilities of this technique.

4) The impression packer is another technique which could prove to be very beneficial in assessing the zone of excavation disturbance. This technique, in conjunction with microscopic examinations, permits the investigator to map the location and extent of features on a borehole wall which may or may not be visible to the human eye. It is suggested that more experimentation should be undertaken with this procedure.

5) The sliding micrometer is a very accurate instrument for measuring displacements in a direction parallel to the borehole axis. Further evaluation of this technique is required to determine its usefulness on a larger scale.

4.0 CONCLUSIONS

Several rock mass characterization techniques have been evaluated under laboratory and/or field conditions in order to assess the mechanical characteristics of plutonic rock of the Canadian Shield. The techniques were carried out in laboratory and field situations away from the URL. This was due to the fact that AECL has postponed some of their programs as a result of their decision to increase the depth of the access shaft. The

techniques and equipment that were addressed include the shallow borehole dilatometer, the deep borehole dilatometer, acoustic stress measurements, the impression packer and the sliding micrometer.

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